

MOVING AVERAGE FILTER FOR RIPPLE CURRENT ELMINATION

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ABSTRACT

In power electronics field concerning power converter applications; current control is becoming one of the key research areas. Typically, in current control applications, the inductor current is shaped to closely follow its reference. This is achieved by regulating the current via current control strategies. The rapid switching of the power semiconductor devices will forms the ripples on the regulated current. In analysis stage, for proper comparison between the regulated current and reference current, it is crucial that the current ripples are eliminated. Common fixed cut-off frequency filter, however, is not suitable in this application due to variable switching frequency nature of some current control techniques. Therefore, in this project, a variable cut-off frequency filtering technique based on numerical algorithm is developed to eliminate the current ripple without destroying the non-ripple data. To verify its performance, the algorithm is tested on several real data of regulated current. Result shows that the algorithm is able to filter the ripple current satisfactorily.

ABSTRAK

Dalam bidang kuasa elektronik mengenai penggunaan penukar kuasa; kawalan arus menjadi salah satu bidang penyelidikan utama. Biasanya, dalam aplikasi kawalan arus, arus pearuh rapat mengikut bentuk arus rujukan. Ini dicapai dengan mengawal selia arus melalui strategi kawalan arus. Pensuisan pesat peranti semikonduktor kuasa akan membentuk riak pada arus yang dikawal. Pada peringkat analisis, perbandingan yang betul antara arus terkawal dan arus rujukan, ia adalah penting untuk riak pada arus dihapuskan. Frekuensi potong yang telah ditetapkan untuk penapis biasa digunakan, walaubagaimanapun, tidak sesuai dalam penggunaan ini kerana frekuensi pensuisan berubah sifat dalam beberapa teknik kawalan arus. Oleh itu, dalam projek ini, kekerapan boleh ubah frekuensi potong untuk teknik penapisan berdasarkan algoritma berangka dibangunkan untuk menghapuskan riak arus tanpa memusnahkan data bukan-riak. Untuk mengesahkan prestasi, algoritma diuji dengan beberapa data arus sebenar yang dikawal selia. Keputusan menunjukkan bahawa algoritma, ini mampu untuk menapis semasa riak memuaskan.

TABLE OF CONTENTS

	Page
SUPERVISOR’S DECLARATION	ii
STUDENT’S DECLARATION	iii
ACKNOWLEDGEMENTS	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF FIGURES	x
CHAPTER 1 INTRODUCTION	
1.1 Introduction	1
1.2 Project Background	2
1.3 Problem Statement	2
1.4 Objectives of the Research	2
1.5 Scope of Project	3
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	4
2.2 Filter Application	4
2.2.1 The Advantages of Adaptive Filter	4
2.2.2 The Functions of Adaptive Filter	5
2.2.3 Moving Average Filter	5
2.3 Extrapolation Application	6

2.3.1	The Midpoint Method	6
2.4	Interpolation Application	7
2.4.1	The Used of Cubic Spline Method	7
2.4.2	The Function of Cubic Spline Method	8
CHAPTER 3	METHODOLOGY	
3.1	Introduction	9
3.2	Extrapolation and Interpolation	10
CHAPTER 4	RESULTS AND DISCUSSIONS	
4.1	Results	12
4.1.1	The span of the moving average is 100	13
4.1.2	The span of the moving average is 200	16
4.2	Discussions	20
CHAPTER 5	CONCLUSION AND RECOMMENDATIONS	
5.1	Conclusion	23
5.2	Recommendations for the Future Research	23
REFERENCES		24
APPENDICES		25
A	Moving Average Filter for Ripple Current Elimination	26

LIST OF FIGURES

Figure No.	Title	Page
3.1	Methodology for ripple current filter design	9
3.2	Block diagram for ripple current filter design	10
4.1	The raw signals of PI current control from Picoscope	12
4.2	The pre-filtered signal of PI current control from Picoscope	13
4.3	The ripple current raw signals in Matlab	13
4.4	The smooth ripple current in Matlab	14
4.5	The local maximum and minimum of ripple current in Matlab	14
4.6	The midpoint of ripple current in Matlab	15
4.7	The ripple current elimination in Matlab	15
4.8	The raw signals of Hysteresis current control from Picoscope	16
4.9	The pre-filtered signals of Hysteresis current control from Picoscope	16
4.10	The ripple current raw signals in Matlab	17
4.11	The smooth ripple current in Matlab	17
4.12	The local maximum and minimum of ripple current in Matlab	18
4.13	The midpoint of ripple current in Matlab	18
4.14	The ripple current elimination in Matlab	19
4.15	The ripple current elimination in Matlab	19
4.16	The example of peak finding for noise in Matlab	20

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Current control regulates the inductor current in power electronics devices to closely follow the reference current. This regulation is carried out by rapid switching of the power semiconductor which forms saw-tooth ripples on the regulated current. Often, the ripples need to be suppressed in data analysis to clearly compare the regulated current and its reference.

Ripple current is an unwanted small change in periodic output variation of the direct current output from an alternating current of a power supply. This ripple is due to incomplete suppression of alternating waveform of source. Ripple is an undesirable in power electronic applications for several reasons and has been considered as an unwanted effect.

Moving average filter is one of the methods that has been used to filter generate input signals in digital form for a better analysis. Moving average digital filter specially designed for this application needed. The moving average operation used in fields is a particular kind of low-pass filter. A low-pass filter is an electronic filter that passes low-frequency signals but reduces the amplitude of signals with frequencies higher than the cut off frequency. So, this is a technique of implementing the introduction of optimum signal current ripple are analysed.

The moving average filter is commonly used for smoothing an array of sampled data or signal. It takes samples of input at a time and takes the average of those samples and produces the desired output. It is a very simple Low Pass Finite Impulse Response (FIR) Filter for filtering the unwanted current ripple from the intended data. The input is current ripple and the aim is to analysis the current ripple.

1.2 PROJECT BACKGROUND

Signal data is something numerical issues that usually very difficult to analyse in real world. Any algorithm method that related to analysis the data would be troubled to obtain and sometimes it is not very easy to use. To this end, the idea of the moving average filter is been developed and by using this process, a set of signal data are been looked for the midpoint and fitted between each of the middle points to find the continuous and smooth curve. So that, the ripple current can be eliminated successfully.

1.3 PROBLEM STATEMENT

Current ripple frequencies are varies, so fixed cut off frequency filter is not effective. The signal is too complicated and difficult to analyze but when the data is been simplified with certain frequency, the desired data is disappear. A filter has been designed, so that it can eliminate the ripple and the analysis on current control can be performed.

1.4 OBJECTIVES OF THE RESEARCH

In this research project, the main objective is to develop a technique based on numerical algorithm for elimination of the current ripple to better analysis performance of current control. To verify the performance of this technique, the

system will be simulated with various data collection using Matlab program and the simulation results will be validated by using the proposed technique. This method should be able to remove the ripple with various cut off frequency and also be able to maintain the overshoot and undershoot on oscillating after being filtered.

1.5 SCOPE OF PROJECT

The scope of the project is about the investigation of any possible technique or filter that can eliminate the current ripple for maximum achievement for better performance of current control in power electronic field.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main intention of this section is to provide a review of past research efforts related to filter used and extrapolation and interpolation technique. An opinion of other relevant study studies is also provided including the currently research effort. The review is show a little bit of scope and direction of this project.

2.2 FILTER APPLICATION

2.2.1 The Advantages of Adaptive Filter

“The adaptive algorithm for FIR filters are is widely used in different applications such as biomedical, communication and control due to its easily implementation, stability and best performance. Its simplicity makes it attractive for many applications where it is needed to minimize computational requirements” [1].

Algorithms that can be adapted for FIR are widely used in various field because it is easy implementation, stable, computation requirement is minimum and best perform. FIR is a type of a signal processing filter which responded to any length input in finite duration.

2.2.2 The Functions of Adaptive Filter

“The notion of making filters adaptive, i.e., to alter parameters (coefficients) of a filter according to some algorithm, tackles the problems that we might not in advance know, e.g., the characteristics of the signal, or of the unwanted signal, or of a system influence on the signal that we like to compensate. Adaptive filters can adjust to unknown environment and even track signal or system characteristics varying over time” [2].

Changing the parameter of a filter according to some algorithms is to address the problem of the signal characteristics by identifying the unwanted signal that give bad influence to the performance of a system. Adaptive filter can be used in different circumstances from time to time. For simple comprehension, adaptive filter is about the changing of coefficient over time which is to adapt the change in signal features.

2.2.3 Moving Average Filter

“A moving average filter is a very simple FIR filter. It is sometimes called a boxcar filter...” [3]

A moving average filter smooth the data by replacing each data point with the average of the neighbouring data points which is defines as range by using simple equation. A boxcar is a railroad car which it is carrying container and also known as goods van or covered wagon and generally used to carry freight. The boxcar is not the simplest freight car design since it can carry more loads. In other words, the container is kind of a boxcar with the wheels and under frame. Moving average filter is one of the methods that can analyse too many data. This is not easy technique to compliance the computation of all data with so many complexities. So that, the filter is much similar as boxcar.

2.3 EXTRAPOLATION APPLICATION

2.3.1 The midpoint method

Area Approximations

“... Before learning how to use anti-derivatives to calculate the exact value of these integrals, students can approximate the value of the area using approximations such as the endpoint methods, the midpoint method and the trapezoid method.”[6]

Methods of Approximation

“The four most common methods of approximating the area between two curves are the left and right endpoint methods, the midpoint method and the trapezoid method...”[6]

Error and Concavity

“... If the error is positive, then the approximation is larger than the actual area; if it is negative, then the approximation is smaller than the actual area. Larger error values indicate greater differences between the actual area and the approximation. Different methods yield different errors depending on the types of curves that bound the area.”[6]

The midpoint rule is one of the fundamental method that learner can be able to calculate the appropriate value of the area. This is the most frequently techniques of approximating the area between two curves. The error values represent the differences between the approximation area and the actual area of curves. The approximation area is larger than the actual area if the error is positive while the approximation area is smaller than the actual area if the error is negative. So, these

kinds of practices have advantages over the area approximations, methods of approximation and error determination. Different methods will generate different assumptions.

2.4 INTERPOLATION APPLICATION

2.4.1 The Used of Cubic Spline Method

“Cubic splines are widely used to fit a smooth continuous function through discrete data. They play an important role in such fields as computer graphics and image processing, where smooth interpolation is essential in modeling, animation, and image scaling. In computer graphics, for instance, interpolating cubic splines are often used to define the smooth motion of objects and cameras passing through user-specified positions in a key frame animation system. In image processing, splines prove useful in implementing high-quality image magnification. Cubic splines interpolate (pass through) the data with piecewise cubic polynomials. The use of low-order polynomials is especially attractive for curve fitting because they reduce the computational requirements and numerical instabilities that arise with higher degree curves. These instabilities cause undesirable oscillations when several points are joined in a common curve. Cubic polynomials are most commonly used because no lower-degree polynomial allows a curve to pass through two specified endpoints with specified derivatives at each endpoint. The most compelling reason for their use, though, is their C2 continuity, which guarantees continuous first and second derivatives across all polynomial segments...”[7]

Cubic splines are used extensively in fitting a smooth continuous function thru discrete data and leading to the important role in various fields with difference usefulness such as the definitions of object's motion, implementing high quality image magnification and any other applications. Cubic splines interpolate the data with piecewise cubic polynomials. The use of low degree order of polynomials is to reduce the computational requirements and numerical instabilities instead higher

degree curves, which may cause the undesirable oscillations when the points are joined in a cubic spline curve. Cubic polynomials are widely used because no lower-degree polynomial allows a curve to pass through two specified endpoints with specified derivatives at each endpoint and the continuity of the first and second derivatives across all polynomial points is been ensured.

2.4.2 The Function of Cubic Spline Method

“... A cubic spline curve is a piecewise cubic curve with continuous second derivative. The resulting curve is piecewise cubic on each interval, with matching first and second derivatives at the supplied data-points. The second derivative is chosen to be zero at the first and last points...”[8]

Piecewise is a function that's a real data changes depending on the value of the independent variable in intervals. That's mean piecewise function is holds for each piece of the data which are known as knots or marks in curve fitting before the interpolation process.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The methodology for this project is shown in **Figure 3.1**. First and foremost, the maximum point is found. Then, the minimum point is found. After that, the maximum and minimum point is connected by using the interpolation. The midpoint is found after the interpolation. By using the spline interpolation, the entire midpoints are connected. All the steps that has been discussed are involved in designing the filter.

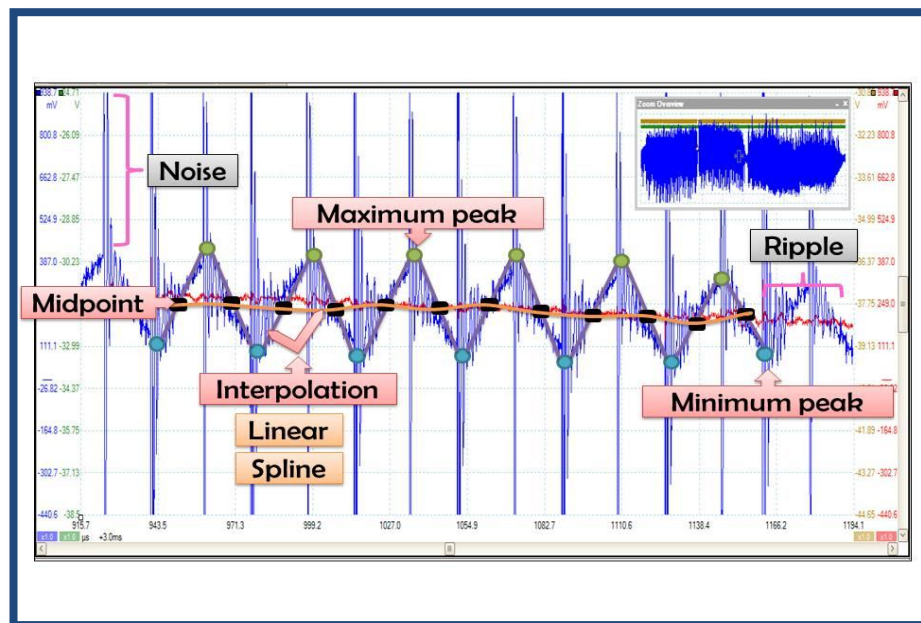


Figure 3.1 Methodology for ripple current filter design

The block diagram for this project is shown in **Figure 3.2** as follow:

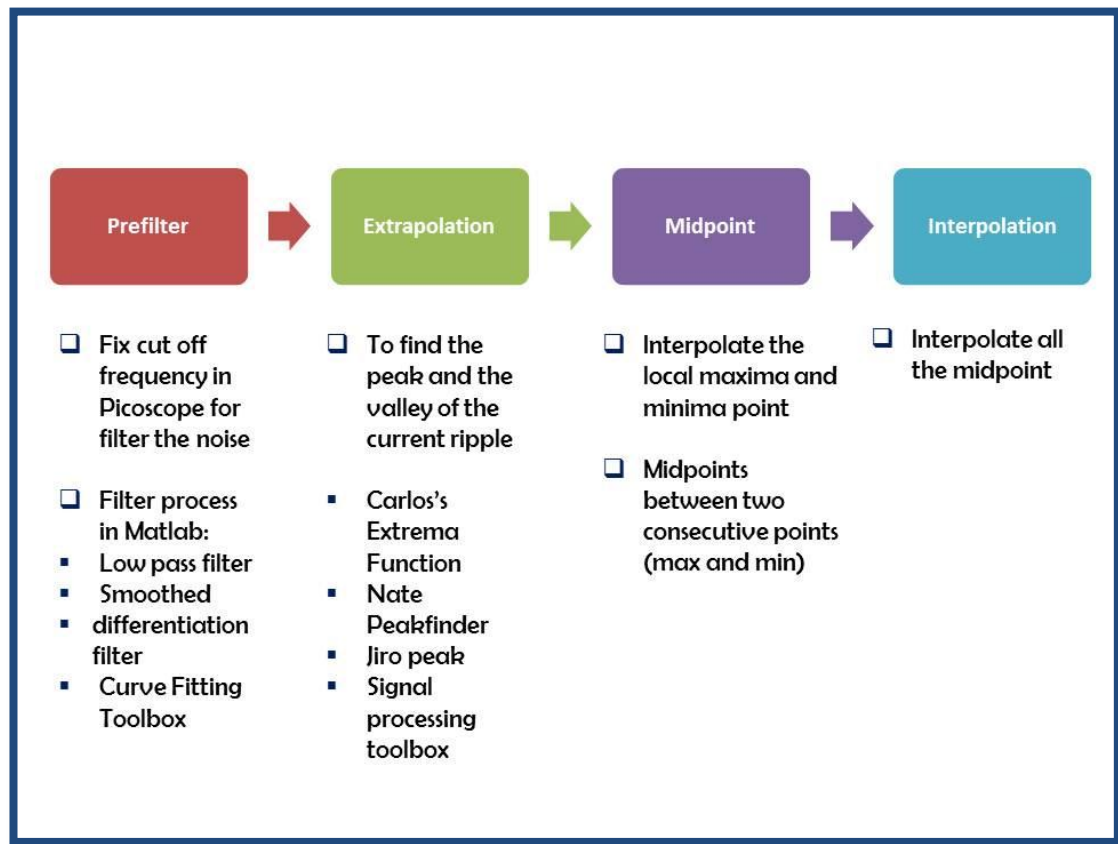


Figure 3.2 Block diagram for ripple current filter design

The input signals data which is current ripple is in digital form. The signal is too complex where the current ripple frequencies are varies with different values of overshoot and undershoot. It takes samples of current input at a time.

3.2 EXTRAPOLATION AND INTERPOLATION

Extrapolation is a method to find the midpoint of graph. There are some choices of which extrapolation method to apply for solving the problem such as linear extrapolation, polynomial extrapolation, conic extrapolation, French curve extrapolation and so on [4]. It depends on the suitability solution based on problem, the smooth of resulting graph and the self-basic knowledge if want to find the best

option. Same goes to interpolation method. Interpolation is kind of way to connect all the midpoint of graph to be a smooth curve. Some of interpolation methods are piecewise constant interpolation, linear interpolation, polynomial interpolation, spline interpolation, Gaussian interpolation and others [5]. The accuracy and the appropriate algorithms used for each method are different. A better way is to find the easy method but give the best performance in curve fitting problems.

The main function of extrapolation methods is to evaluate the large numbers of data point with highly precision by applying various numerical methods to find the middle point of the signal after been filtered with various cut off frequency. The main application of interpolation techniques is for curve fitting which is simple, can fit to any kind of data set, no matter how random the data may be seem and effectively and efficiently connect all the midpoints with smooth pattern signal. The development of this practices combination with simplest algorithms and straight forward will contribute the solution towards the ripple current elimination in real situations. Applying a simple rules will makes these methods extremely powerful, expeditious and accurate in the process.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 RESULTS

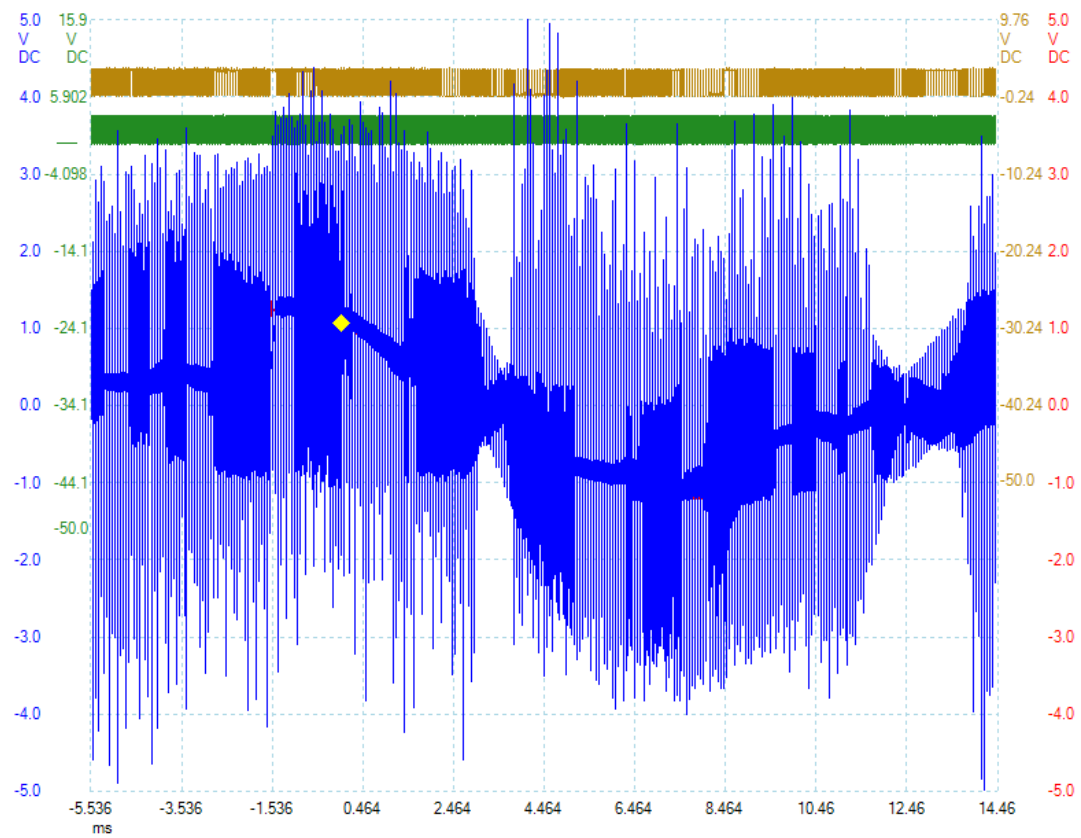


Figure 4.1 The raw signals of PI from Picoscope

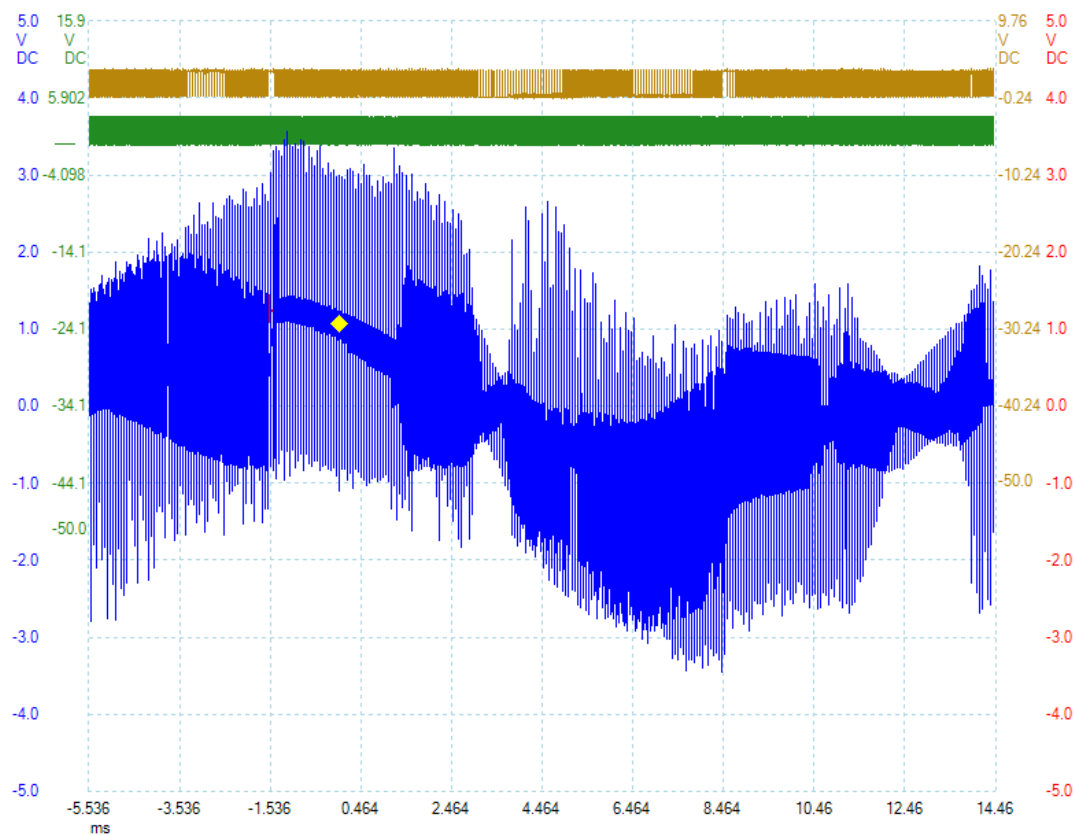


Figure 4.2 The pre-filtered signal of PI from Picoscope

4.1.1 The span of the moving average is 100

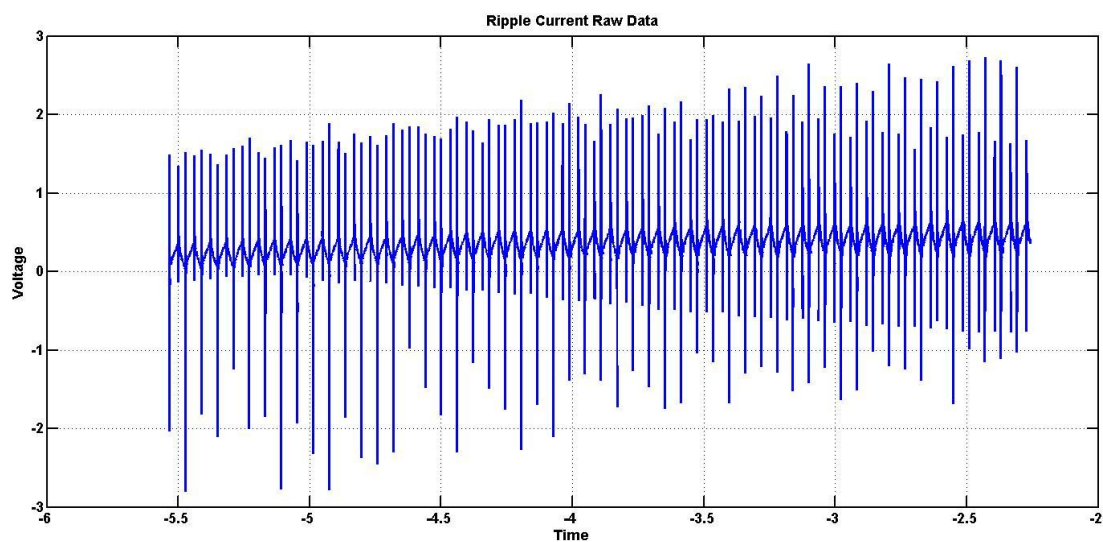


Figure 4.3 The ripple current raw signals in Matlab

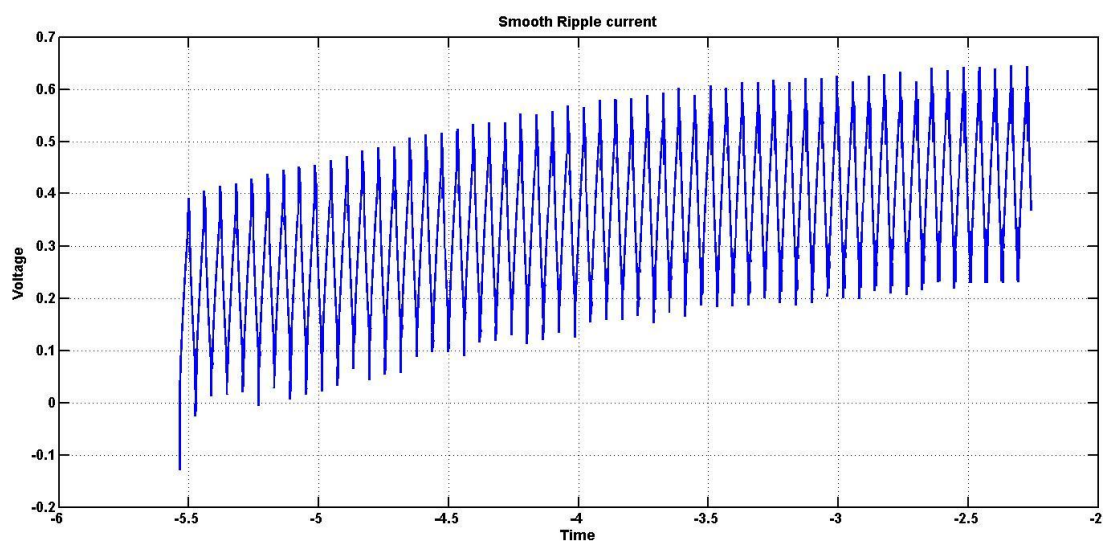


Figure 4.4 The smooth ripple current in Matlab

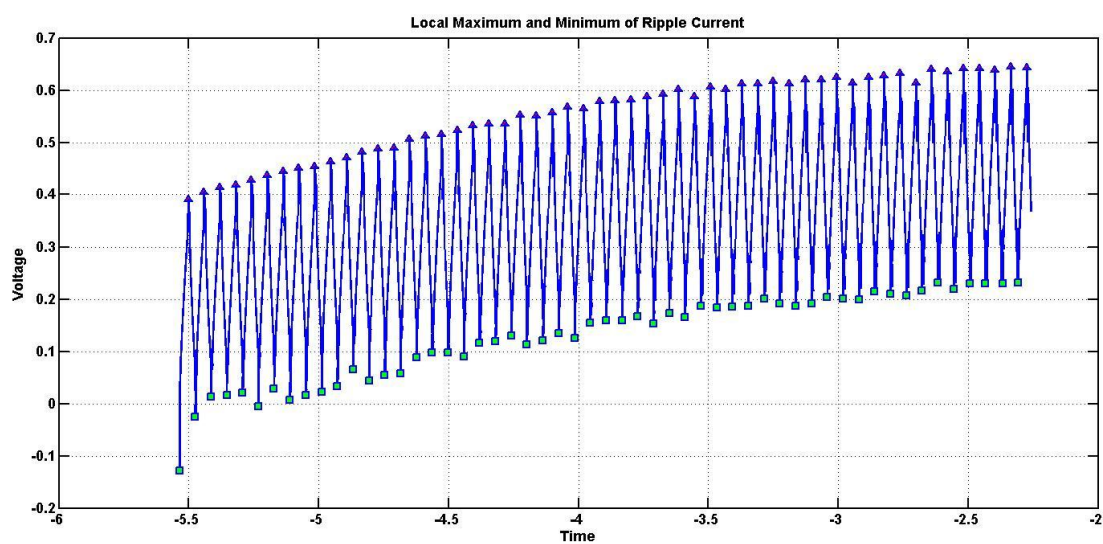


Figure 4.5 The local maximum and minimum of ripple current in Matlab

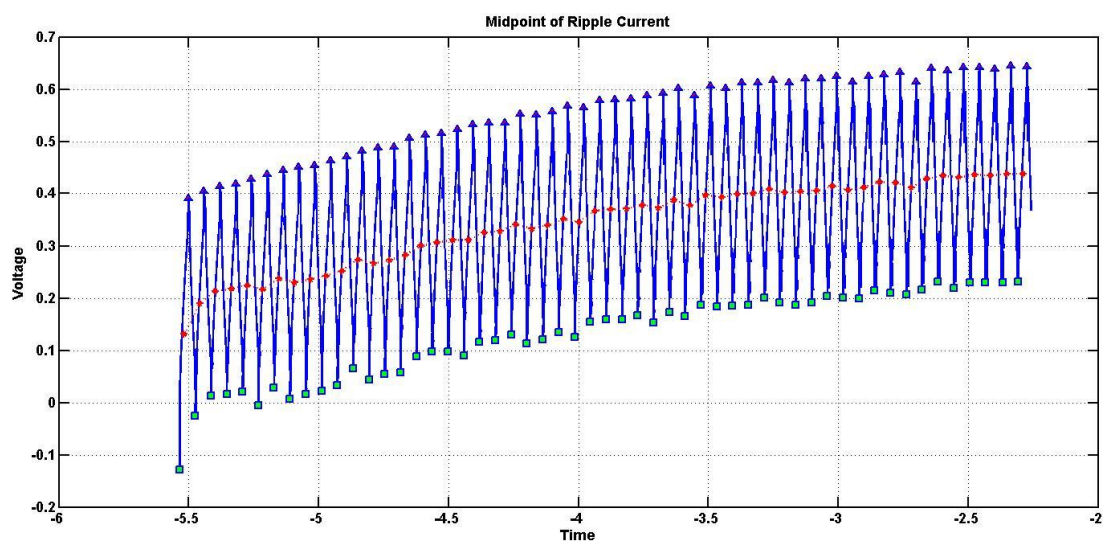


Figure 4.6 The midpoint of ripple current in Matlab

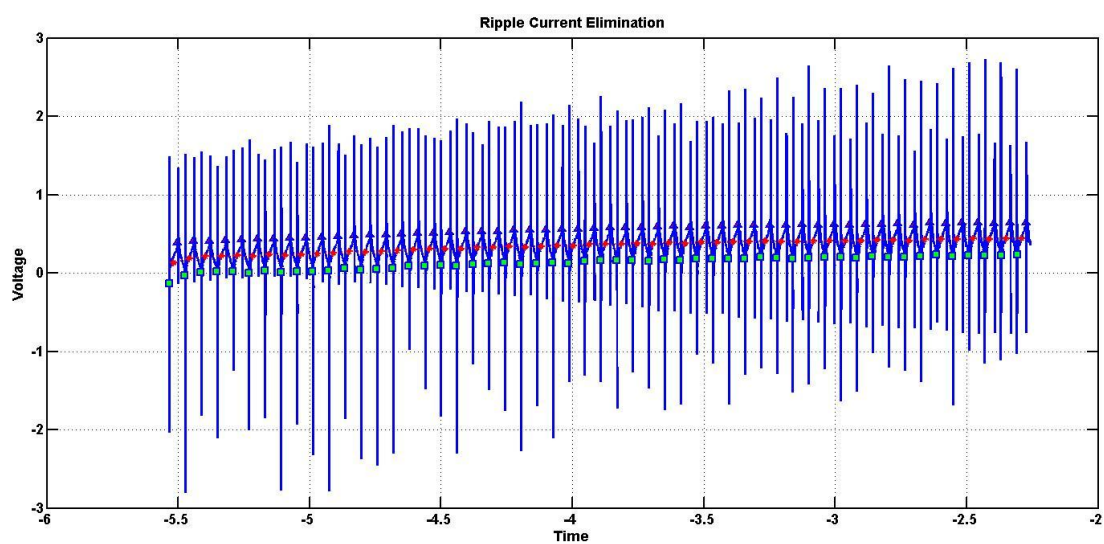


Figure 4.7 The ripple current elimination in Matlab

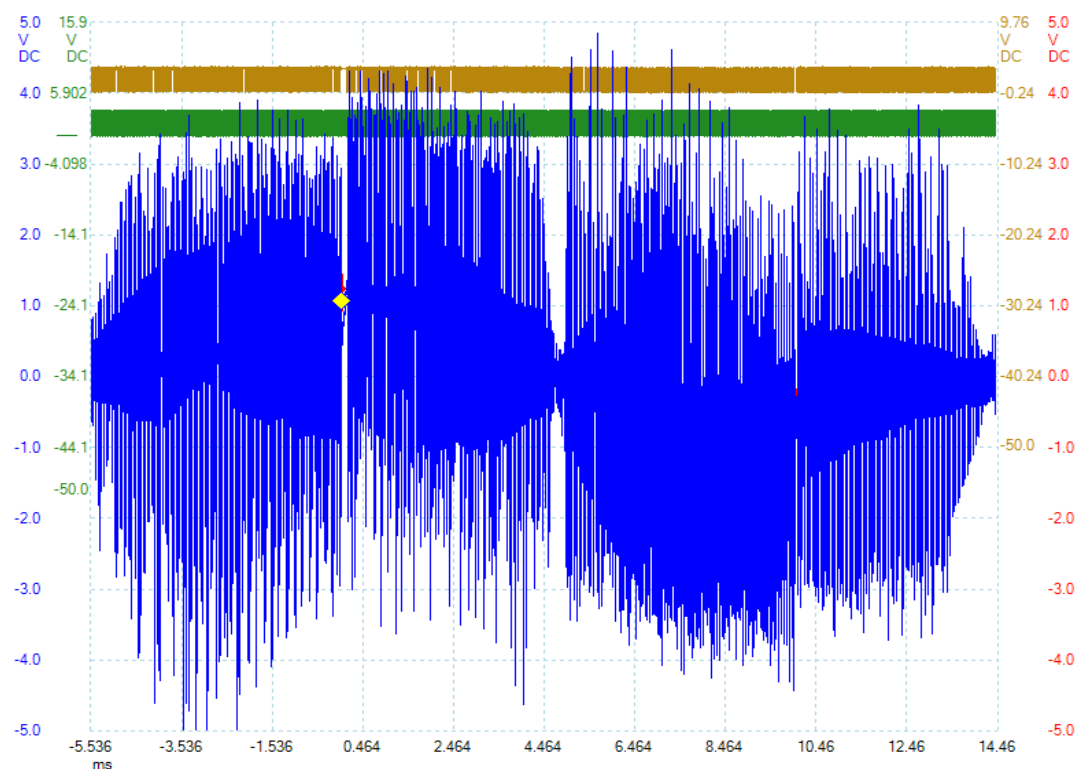


Figure 4.8 The raw signals of Hysteresis from Picoscope

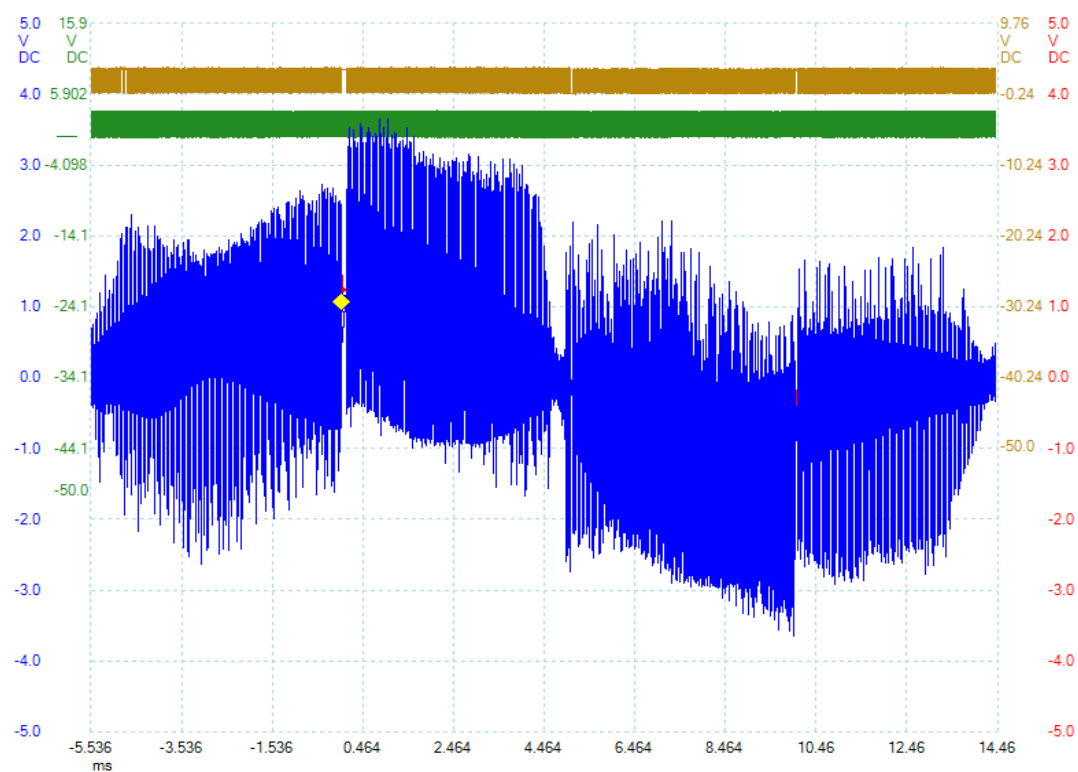


Figure 4.9 The pre-filtered signal of Hysteresis from Picoscope

4.1.2 The span of the moving average is 200

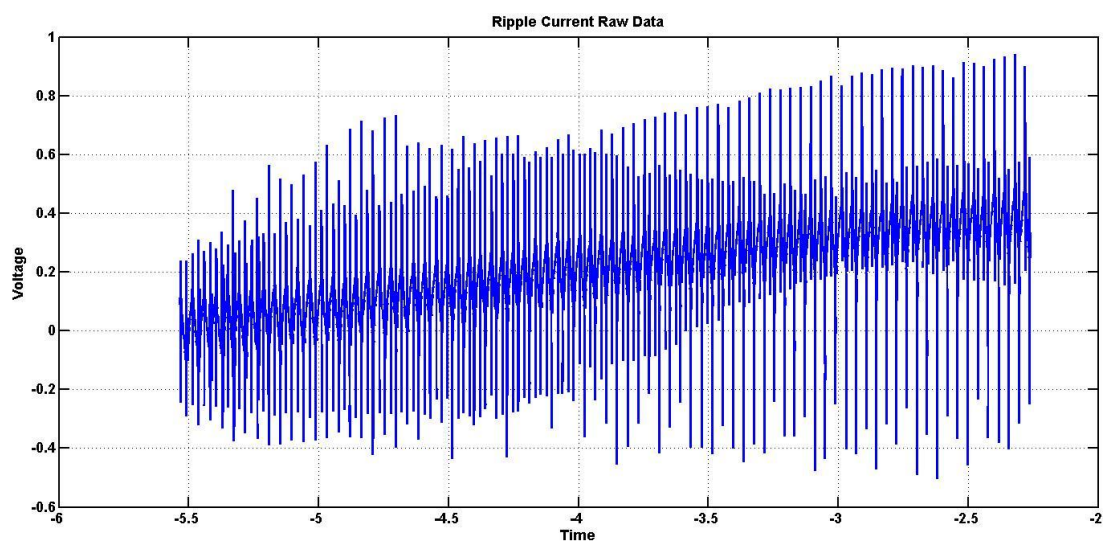


Figure 4.10 The ripple current raw signals in Matlab

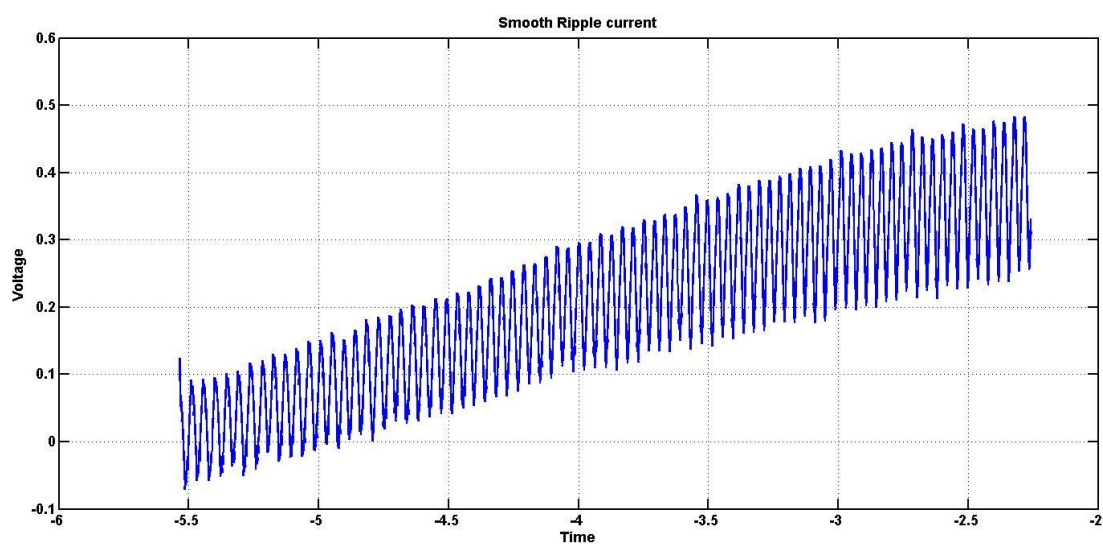


Figure 4.11 The smooth ripple current in Matlab

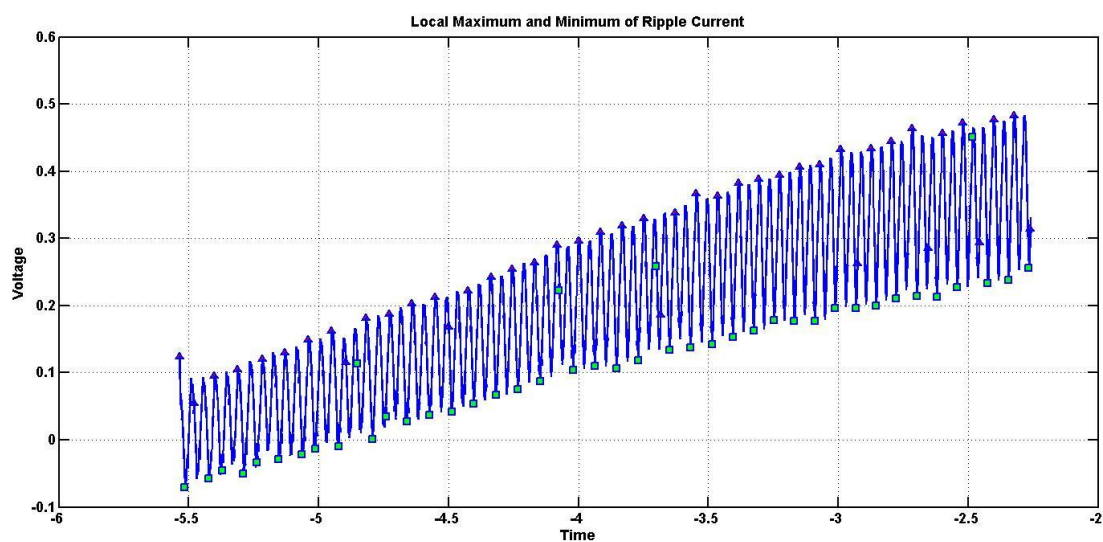


Figure 4.12 The local maximum and minimum of ripple current in Matlab

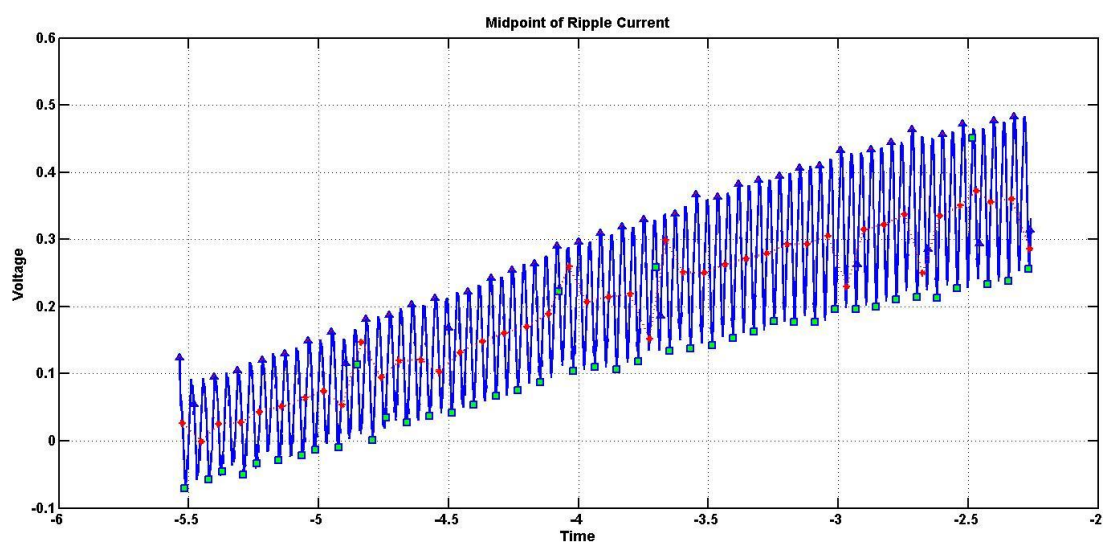


Figure 4.13 The midpoint of ripple current in Matlab